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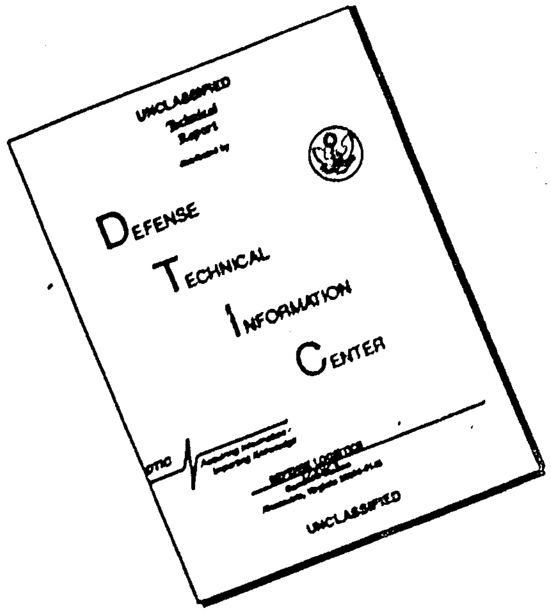

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TECHNICAL REPCRT 2259

AN ORDER OF MAGNITUDE LETHALITY ANALYSIS OF FLECHETTE-LOADED CANISTER AMMUNITION (C)

FC

MARVIN B. SCHAFFER

OCTOBER 1955

SAMUEL FELTMAN AMMUNITION LABORATORIES
PICATINNY ARSENAL
DOVER, N. J.

ORDNANCE PROJECT TA1-5003
DEPT. OF THE ARMY PROJECT 5A04-01-002

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OBJECT

To investigate the effect of varying the flechette size and the cone angle of dispersion on the lethal potential of a round of 75 mm canister ammunition.

SUMMARY

The 75 mm canister, T30 series, was analyzed using the lethal-area, single-shot concept. Velocity decay curves and a provisional casualty criterion from the data in the available literature were estimated and were used for this purpose. The calculations revealed that an 8-grain fragment and a cone angle of dispersion of 6° will produce the most effective weapon for the first 1000 feet of range; the expected lethal area for this combination is 29,000 square feet, an eighteenfold increase over the T30E2 ball-loaded canister previously submitted to the Field Forces. The calculations further showed that for that portion of the field of fire extending to the maximum lethal range a larger fragment (heavier than 18.5 grains) and a smaller cone angle (approximately 1°) will produce the greatest number of enemy incapacitations. The lethal area for this combination is approximately 65,000 square feet. Only 14% of these incapacitations will, however, occur to troops in the first 1000 feet of range, where the greatest threat from a massed infantry assault exists.

RECOMMENDATIONS

It is recommended that this analysis be repeated when more refined data become available and that the tentative conclusions then be re-examined.

INTRODUCTION

1. The work described in this report was performed under Project TA1-5003, Research and Development of Fin-Stabilized Fragments and Projectiles. The major agencies involved are Picatinny Arsenal, Dover, New Jersey; Watertown Arsenal, Watertown, Massachusetts; and International Harvester Company, Evansville, Indiana. This work is part of the research phase of the optimum canister ammunition program for calibers ranging from 40 mm to 120 mm. The 75 mm T30 canister is the prototype for ultimate canister ammunition design in all other calibers.

THE PROBLEM

2. The problem was to investigate the effect of varying flechette size and cone angle of dispersion on the lethal potential of a round of 75 mm canister ammunition. The method of analysis chosen was the single-shot defensive lethal area concept (Refs 1 and 2) dictated, in the case of tank systems, by the stowage problems inherent in special-purpose canister ammunition.

3. To apply to flechette-loaded canister the same analysis that had previously been used to evaluate ball-and-slug loaded items, it was necessary that the following data be available:

a. Fragment damage and payload data
b. Initial fragment attitude (or yaw angle) data
c. Velocity decay data for all angles of initial attitude
d. A casualty criterion for assessing the lethal effect of a single directionalized fragment

4. It was also necessary to develop a statistical method of adding the contributions of each group of fragments (classified by initial attitude) to obtain the total effect of all fragments at each range. This calculation was not required for ball-loaded canister, since all spherical fragments have essentially the same velocity decay characteristics.

5. Much of the data used in the present report was either interpolated or estimated, and therefore the calculations and conclusions drawn can serve only as order-of-magnitude approximations. Within this framework, however, several important conclusions can be reached regarding:

a. The effectiveness of flechette-loaded canister as compared with the equivalent ball-loaded canister.
b. The effect of varying the cone angle of dispersion.

6. Precise calculations regarding "optimum" cone angles and "optimum" flechette weights must await more refined data. However, it is considered that reasonable results are obtained herein.

THE FAMILY OF FLECHETTES STUDIED--PARAMETERS COMMON TO ALL

7. The parameters common to all designs studied in this report are summarized in Table 1. The maximum cone angle of dispersion (13.58°) and the payload (41%) had been previously attained with the 75 mm canister, T30E10 (Ref 3). With this design, approximately 35% of the fragments were damaged in firing. However, it appears reasonable to assume that this percentage will be reduced as the development proceeds. A damage figure of 20% was, therefore, assumed and used throughout this study. (This corresponds to an effective payload of 4.8 lbs per canister. All damaged fragments are assumed to be ineffective.)

8. The approximate dimensions of the family of flechettes studied (6 - 18.5 grains) are given in Table 2. The dimensions of the 8-grain fragment correspond to International Harvester Company design FL-17; the dimensions of the 12 and 18.5-grain fragments correspond to Rheem Manufacturing Company models 10f and Xb, respectively. All other weights are scaled from these designs. A qualitative sketch of the family of flechettes is shown below.

9. The choice of dimensions for scaling the flechettes was largely a matter of judgment. A search of the literature failed to reveal any close agreement among the various contractors involved in developing weapons using flechette loads, except that all were agreed the fragments should have four fins. Most contractors were also agreed than an all-steel, straight-bodied fragment would be satisfactory. A tapered body or a weighted nose fragment had previously been tested by several contractors and been found to be of marginal value. One contractor strongly

recommended the use of steel nose, plastic boom and fin assemblies; another considered the use of brass fragments; and a third advocated the use of all steel fragments, but with 2° canted fins. Any of these modifications might have a significant effect on the performance of the weapon, from both an aerodynamic standpoint and a wound ballistics standpoint. However, it is considered that none would invalidate the findings of this order-of-magnitude study. The wound ballistics estimates used in this report were based in part on performance of the Armour 8-grain fragment which has a nose angle of about 45°. Since this variable is thought to have considerable influence on the penetrating ability of the fragment, it is suggested that it be made a common feature of the family of flechettes.

INITIAL FRAGMENT ATTITUDE AND VELOCITY DECAY DATA

10. The velocity decay of a finned fragment depends on the following factors:

a. Initial attitude.
b. Initial velocity.
c. Weight of fragment.
d. Distance between center of pressure and center of gravity (controlling before stability is achieved, if fragment is unstably launched).
e. Drag inducing contour (controlling after stability is achieved).
f. All other factors including initial angular velocity, cross-winds, etc.

11. Among the earliest contractors to recognize this condition was A. D. Little, Inc., engaged in developing a warhead for a rocket application. After some preliminary theoretical work (based on maximizing the distance between center of pressure and center of gravity), experimental firings of individual fragments of more than a dozen designs were conducted. Fragments were launched both fin-first and point-first, and both supersonically and subsonically. This work, which is summarized in Reference 4, has found little general application, however, because:

a. All fragments were limited to an 8 grain weight, and
b. The range over which data was obtained was only 100 feet.

12. Some typical velocity decay curves for A. D. Little flechettes are reproduced in Figures 1 and 2. To provide a common basis for comparing the velocity decay curves of all contractors, it was necessary to extrapolate the data to a common initial velocity, 2030 ft/sec. The accepted drag equation, $V/Vc = e^{-KR}$ was used for this purpose.

13. Shortly after the A. D. Little investigation, a completely theoretical study of the behavior of finned fragments under different conditions of initial launch was prepared by Aircraft Armaments, Inc. (Ref 5). Among the fields investigated in this study were: velocity-range losses due to initial angular velocity (tumbling), range at which tumbling ceases and oscillation starts, and velocity-range losses due to oscillation. Some theoretical equations were also presented for stably launched fragments. Among the more important conclusions reached was that a fragment launched with an angular velocity of less than 1000 radians per second will behave in essentially the same way as a fragment launched fin-first ($\theta = \pi$) with zero angular velocity. A curve was also furnished for a fragment launched sideways ($\theta = \pi/2$). This fell between the $\theta = \pi$ and $\theta = 0$ curves but closer to $\theta = \pi$ curve.

14. Aircraft Armaments' theoretical curves were for a 16-grain fragment. The $\theta = \pi$ and $\theta = 0$ curves for this fragment are reproduced in Figures 3 and 4, respectively. Subsequent investigations, by Rheem Manufacturing Company (Ref 6) and later by Aircraft Armaments (Ref 7), revealed that the $\theta = \pi$ curve predicted too rapid a fall-off and the $\theta = 0$ curve too little fall off. The latest Aircraft Armaments designs (models D and C, whose velocity decay characteristics are also shown on Figures 3 and 4), when tested experimentally over a 300-foot range produced results which are fairly consistent with the findings of Rheem Manufacturing Company. The latter weighed approximately 11 grains.

15. The most extensive velocity decay data was gathered by Rheem Manufacturing Company (Ref 8). Rheem's data covered two fragment weights, 18.5 and 12 grains (models Xb and 10f) and included a considerable range of initial velocities (the highest 2400 fps). The data, which were collected over a 700-foot range for the fin-first firings, were extended to about 2500 feet by piecing together adjacent nose-first curves. Unstable and stable launch curves for these fragments are given in Figures 3 and 4, respectively. Rheem also extrapolated this data (using the drag equation discussed previously) to obtain curves (Figs 1 and 2) for an 8-grain fragment (model 10b).

16. Additional velocity decay data available at the time of writing included some estimates by International Harvester Company for an 8-grain fragment (personal communication). These curves (Figs 1 and 2) are fairly consistent with A. D. Little's data and Rheem's extrapolation except that the final velocity fall-off appears to be too rapid. In addition, some experimental data for a 22-grain fragment (model FL-7A) were obtained over a 75-foot range (Ref 9). However, these data (Fig 4) are too limited to be conclusive.

17. Of all the data available, the curves of Rheem Manufacturing Company appear to be most reliable. These are reproduced as solid curves on Figures 5 and 6 for stable and unstable launches, respectively. The dashed curves for 6, 10, 14, and 16 grains are interpolated. It is to be noted that these curves do not necessarily represent the family of flechettes studied in this report, particularly in the range of 6-10 grains. However, within the framework of an order-of-magnitude analysis, they are considered adequate.

18. Data on the initial flechette attitude distribution were completely lacking. It was considered reasonable to assume, however, that no fragments would be launched with an angular velocity greater than 1000 radians per second, and therefore, the worst condition of launch would be the fin-first ($\theta = \pi$) curve. It was further hypothesized that the distribution of initial flechette attitudes would be essentially random between the limits of the $\theta = \pi$ curve and the $\theta = 0$ curves, and that this condition would be relatively unaffected by the method of stacking the fragments within the container. As an approximation, therefore, 1/3 of the undamaged fragments were assumed to be launched with a $\theta = \pi$ attitude, 1/3 with a $\theta = \pi/2$ attitude, and 1/3 with a $\theta = 0$ attitude. The velocity decay for the $\theta = \pi/2$ launch was taken as midway between the other two curves.

19. Considering the type of analysis conducted, the assumptions made regarding the distribution of initial flechette attitudes will not lead to serious errors. This is particularly evident upon close comparison of Figures 5 and 6. The difference in equivalent range between a stable and unstable launch is usually no more than 150 - 300 feet, considerably less than one might expect. The stable launch curves apparently drop off quite rapidly, initially, since the velocities are in the critical region of Mach numbers. This is the same region in which $\theta = \pi$ and $\theta = \pi/2$ launches show a large velocity drop due to stabilization. Hence, essentially the same conclusions would have been reached regardless of the assumptions made concerning the initial flechette attitude distribution.

A PROVISIONAL CASUALTY CRITERION FOR DIRECTIONALIZED FRAGMENTS

20. The family of curves (Fig 7) entitled "Provisional Probability that a Single Hit Will Incapacitate Assault Troops", are inferred from data presented in Table IV of Reference 10 for the Armour 8-grain flechette. It is estimated therein that the 8-grain fragment will perform as follows:

SINGLE HIT INCAPACITATION PROBABILITIES ($P_{H,K}$)

Incapacitation Time:		30 secs	5 mins	30 mins	12 hours
	Under 200 fps	--------Ineffective-----			
STRIKING	450 fps	0.11	0.14	0.18	0.26
	900 fps	0.17	0.24	0.29	0.41
VELOCITIES	900-1800 fps	0.17	0.24	0.29	0.41
	Over 1800 fps	More effective because of likelihood of tumbling in the wound.			

21. The generalization to flechette weights other than 8 grains, is made on the assumption that penetration into human tissue is proportional to MV/A (for non-tumbling fragments) and that equal penetrations will result in equal probabilities of incapacitation ($P_{H,K}$). As in Reference 1 (for random-shaped fragments), the data have been plotted on a semi-logarithmic scale with time to incapacitation as abscissa and MV/A as parameter. The data have again been found to correlate to straight lines. The dashed lines shown in Figure 7 are interpolations.

22. As mentioned previously, it is suggested that the data are applicable only to fragments duplicating the nose contour of the Armour fragment (45° nose angle). Data recently presented by the Chemical Corps indicate that serious deviations from the MV/A correlation will result from disregarding this limitation.

MODIFICATIONS TO STATISTICAL THEORY PREVIOUSLY USED FOR CANISTER EVALUATION

23. Since it was assumed in this analysis that essentially three groups of effective fragments are simultaneously launched ($\theta = \pi$, $\theta = \pi/2$, and $\theta = 0$), it was necessary to develop a method of adding the contributions of three groups, to obtain the total probability of incapacitation (P_K) at each range. Rigorously,

$$
\begin{aligned}
P_K = {} & (P_{K\pi})(1-P_{K0})(1-P_{K\pi/2}) + (P_{K0})(1-P_{K\pi})(1-P_{K\pi/2}) + (P_{K\pi/2})(1-P_{K\pi})(1-P_{K0}) \\
& + (P_{K\pi}P_{K0})(1-P_{K\pi/2}) + (P_{K\pi}P_{K\pi/2})(1-P_{K0}) + (P_{K0}P_{K\pi/2})(1-P_{K\pi}) \\
& + (P_{K\pi}P_{K0}P_{K\pi/2})
\end{aligned}
$$

$$P_K = P_{K\pi} + P_{K0} + P_{K\pi/2} - P_{K\pi}P_{K\pi/2} - P_{K\pi}P_{K0} - P_{K0}P_{K\pi/2} + P_{K\pi}P_{K0}P_{K\pi/2}$$

24. The individual P_K's of each group can be readily evaluated by the binomial theorem as follows (Ref 2):

$$P_{K\pi} = 1 - (1 - P_{H,K\pi})^{E_{H\pi}}$$
$$P_{K0} = 1 - (1 - P_{H,K0})^{E_{H0}}$$
$$P_{K\pi/2} = 1 - (1 - P_{H,K\pi/2})^{E_{H\pi/2}}$$

where E_H is the expected number of hits per target in each group.

25. For the type of analysis contained in this report, it is more convenient to substitute the Poisson approximation for the binomial distribution, since simplified numerical procedures will result. Hence:

$$P_K = 1 - e^{-E_K}$$

where E_K is the expected number of incapacitating wounds per target.

$$E_K = E_{K\pi} + E_{K0} + E_{K\pi/2} = (E_{H\pi}\, P_{H,K\pi}) + (E_{H0}\, P_{H,K0}) + (E_{H\pi/2}\, P_{H,K\pi/2})$$

However, since it has been assumed that:

$$E_{H\pi} = E_{H\pi/2} = E_{H0} \text{ AND } E_H = E_{H\pi} + E_{H0} + E_{H\pi/2}$$

$$\therefore E_K = \frac{E_H}{3}\left(P_{H,K\pi} + P_{H,K0} + P_{H,K\pi/2}\right) = \frac{E_H}{3}\left(\sum P_{H,K}\right)$$

$$\text{AND } P_K = 1 - e^{-\frac{E_H}{3}\left(\sum P_{H,K}\right)}$$

26. All other statistical calculations are the same as those given in References 1 and 2.

SAMPLE CALCULATION

27. A sample calculation for an 8-grain fragment, a cone angle of 8°, and at a range of 400 feet is as follows:

a. T = time to incapacitate $= \frac{R-100}{60\, V_e} = \frac{400-100}{60\ (15)} = 0.33$ minutes

V_e is assumed velocity of advancing enemy = 15 ft/sec.

b. Fragment velocities:

$V_{\theta = \pi} =$ 560 ft/sec (Figure 6)

$V_{\theta = 0} =$ 1050 ft/sec (Figure 5)

$$V_{\theta = \pi/2} = \frac{V_{\theta=\pi} + V_{\theta=0}}{2} = 805 \text{ ft/sec.}$$

c. $M/A = 8/.00619 = 1290$ grains/in^2 — M is mass of fragment in grains

d. $\frac{MV_{\pi}}{A} = (1290)\ (560) = 0.723 \times 10^6$ — A is projected area of fragment in in^2

$\frac{MV_0}{A} = (1290)\ (1050) = 1.36 \times 10^6$ — V is velocity of fragment in ft/sec

$\frac{MV_{\pi/2}}{A} = (1290)\ (805) = 1.04 \times 10^6$

e. $P_{H,K\pi} = 0.125$ (From Figure 7)

$P_{H,K0} = 0.157$

$P_{H,K\pi/2} = 0.156$

$\Sigma P_{H,K} = 0.438$

f. $E_H = S\Omega = S\left[\frac{N}{2\pi R^2(1-\cos\alpha)}\right] = \frac{(5.35)\ (4200)}{(400)^2\ (.0024)} = 9.3$ hits/target

where S = area of target = 5.35 ft^2

N = effective number of fragments = 4200

R = range = 400 feet

α = 1/2 cone angle = $4°$

g. $E_K = \frac{E_H}{3}(\Sigma P_{H,K}) = \left(\frac{9.3}{3}\right)(.438) = 1.36$

h. $P_K = 1 - e^{-E_K} = 1 - e^{-1.36} = 0.743$

i. $\frac{\pi\alpha}{90} P_K R = \frac{(3.14)\ (4)}{90}(.743)\ (400) = 41.5$ feet

RESULTS

28. Plots of $\pi\alpha/90\, P_K R$ have been made for 7 weights of flechette (6,8,10,12,14,16, and 18.5 grains) for each of 7 cone angles of dispersion (1°,2°,3°,5°,8°,11°, and 13.6°) and are shown as Figures 8-14. A similar plot for the T30E2 ball-loaded canister (cone angle 13.6°) is also shown for comparative purposes (Fig 9).

29. The areas under the above curves have been computed for two limiting conditions, 100 feet to the full maximum lethal range and 100 feet to 1000 feet. The results (lethal area in square feet) are tabulated in Tables 3 and 4. The lethal area for the T30E2 canister is 1620 square feet.

30. Lethal area for the two limiting conditions described above is plotted against flechette weight (with cone angle as parameter) in Figures 15 and 16. A considerable scattering of points in the range of 8-10 grains was obtained but a smooth curve was estimated. Scattering in the 8-10 grain range was probably due to unequal scaling of dimensions between the Rheem 12-grain (model 10f) and the International Harvester Company 8-grain (design FL-17) flechettes.

31. Since the entire family of curves on Figure 16 reached maxima at about 8 grains, the lethal areas for this weight were plotted against cone angle (Fig 17) reaching a maximum at approximately 6°.

DISCUSSION

32. Examination of the full-range lethal area plot (Fig 15) reveals that the maximum lethal area is reached at a very small cone angle (1-2°) and at a large flechette weight (heavier than 18.5 grains). The maximum lethal area (approximately 65,000 square feet) is more than twice that obtainable with the optimum flechette size (10 grains) for the maximum cone angle. The trend indicated by this family of curves is: **the wider the cone angle the lighter the** optimum fragment.

33. Deeper reflection reveals, however, that a misleading conclusion has been reached. The tactical situation for which the ammunition is intended (defeat of a massed infantry assault) calls primarily for close range defense beginning at about 1000 feet from the weapon. A massed infantry assault even though it began at ranges of 3000 feet or more would probably be totally invisible to the defending crew until the closer range is reached (Ref 12). It appears advisable therefore to cut off the lethal area integrations at 1000 feet and re-examine the conclusions.

34. Figure 16, the plot of the latter condition, yields a completely different result. The optimum flechette weight is now approximately 8 grains regardless of the cone angle. Furthermore, a cone angle of 13.6° will yield 3 times the number of incapacitations that a 1° cone angle will. It is especially noteworthy that only 14% of the incapacitations obtained for full range with the combination of 18.5 grains and 1°, will occur in the first 1000 feet. Thus, the area in which the greatest destruction is desired is the least affected.

35. The plot of lethal area vs cone angle for the optimum flechette weight (Fig 17) reveals 6° to provide maximum lethal area. Angles smaller than 6° yield a rapid fall-off in lethal area while larger angles result in a much less rapid decrease. Thus, the maximum cone angle (13.6°) provides 23,000 square feet of lethal area, a decrease of only 20% from the optimum cone angle. When this is compared with the lethal area of the T30E2 canister (1620 square feet), the drop is insignificant.

36. It is thus evident that **all** combinations of an 8-grain fragment and a cone angle larger than 6° will yield from 14 to 18 times the lethal potential of the T30E2 canister. Below 6° or 8 grains, the lethal area falls off rapidly. Flechette weights greater than 8 grains (up to 18.5 grains) will not produce large decreases of lethal area, if the cone angle is approximately 6°. For larger cone angles, however, the decreases with increasing fragment size are significant. These conclusions are, of course, tentative since they are subject to the restrictions of the order-of-magnitude analysis conducted.

37. The concept of restricted cone angles of dispersion is a relatively recent one for canister ammunition. All previous ball and slug loaded items have been designed for the maximum spread obtainable (limited by the twist of weapon and usually 9-14°, Refs 2 and 11). Since the lethal ranges attained by these items were comparatively short, serious deviations from the optimum did not occur (the present study indicated that the shorter the lethal range, the larger the optimum cone angle). For the longer ranges obtained with flechette payloads, however, more serious discrepancies are present. Restricted cone angles are thought to be obtainable by the use of restraining matrix materials or by substituting smaller and weaker rotating bands or by combinations of the two. It is recommended, however, that experimental confirmation of the present theoretical work be obtained before expenditures are made on canister models exhibiting the restricted cone angle properties described herein.

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TABLE 1

PARAMETERS COMMON TO ALL DESIGNS

Muzzle Velocity: 2030 feet/sec

Maximum Cone Angle: 13.58° (Reference 3)

Projectile Weight: 14.7 lbs

Payload: 41% (6.0 lbs)

Assume: 20% Fragment Damage Due to Setback

Effective Payload: 4.8 lbs

TABLE 2

CHARACTERISTICS OF FRAGMENTS EVALUATED

Weight (grains)	Approx. Body Diameter (")	Approx. Fin Span (")	Projected Area (in^2)	Approx. Number Effective Frags. in Canister
6	0.067	0.160	0.00539	5,600
8	0.072	0.178	0.00619	4,200
10	0.086	0.221	0.0098	3,360
12	0.090	0.231	0.0105	2,800
14	0.094	0.250	0.0119	2,400
16	0.097	0.257	0.0125	2,100
18.5	0.100	0.266	0.0132	1,820

Fin Thickness: .0155" (except 6 & 8 Grains: .010")
Nose Angle: 45°

TABLE 3

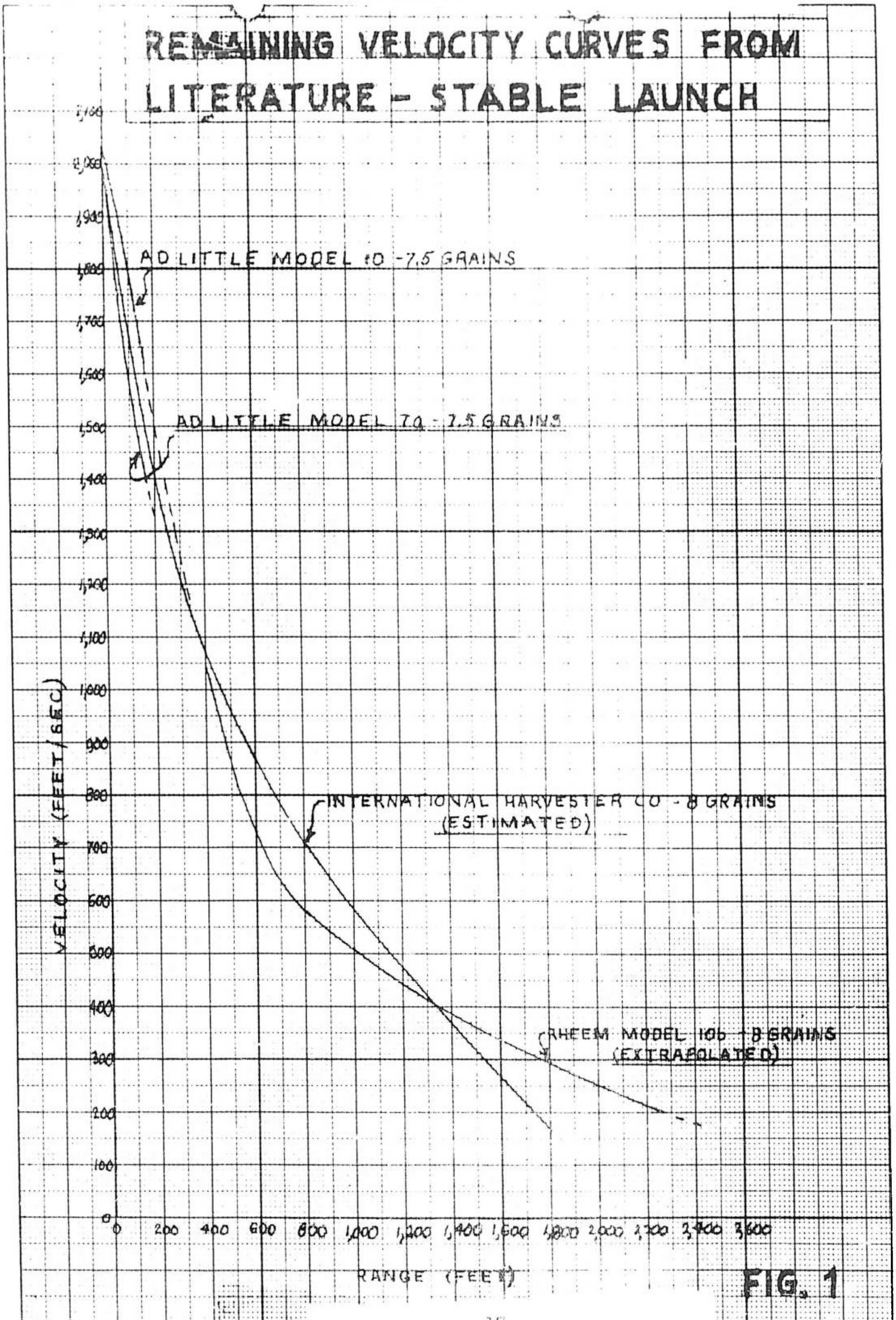
LETHAL AREA (FULL RANGE)
(Ft ^{2})

Flechette Wt. (gr):	18.5	16	14	12	10	8	6
2α (°)							
1	60,000	55,200	49,600	46,700	33,600	34,300	8,360
2	64,100	61,900	58,600	56,300	44,100	49,900	14,500
3	58,300	57,300	56,000	54,700	45,800	50,000	17,700
5	46,500	47,600	47,500	48,500	42,500	45,300	21,400
8	35,300	36,900	38,200	39,200	36,500	41,900	22,700
11	28,100	29,700	30,700	32,700	30,600	36,000	21,800
13.6	23,500	25,000	26,500	28,100	26,800	32,200	20,400

TABLE 4

LETHAL AREA (RANGES OF 100-1000 FT)
(Ft^2)

Flechette Wt. (gr):	18.5	16	14	12	10	8	6
2α (°)							
1	8,710	8,560	8,810	8,860	8,760	8,760	8,190
2	16,400	16,800	16,600	17,100	16,900	17,200	14,400
3	20,800	21,600	22,100	22,800	22,800	23,400	17,600
5	22,000	23,800	24,900	26,600	26,700	29,400	21,300
8	19,600	21,600	23,300	24,900	25,900	29,400	22,600
11	16,400	18,200	20,100	22,000	23,000	26,900	21,700
13.6	14,100	15,700	17,400	19,300	20,800	24,600	20,400



REMAINING VELOCITY CURVES FROM LITERATURE - STABLE LAUNCH
AD LITTLE MODEL 10 - 7.5 GRAINS
AD LITTLE MODEL 7a - 7.5 GRAINS
INTERNATIONAL HARVESTER CO - 8 GRAINS (ESTIMATED)
RHEEM MODEL 106 - 8 GRAINS (EXTRAPOLATED)
VELOCITY (FEET/SEC)
RANGE (FEET)

FIG. 1

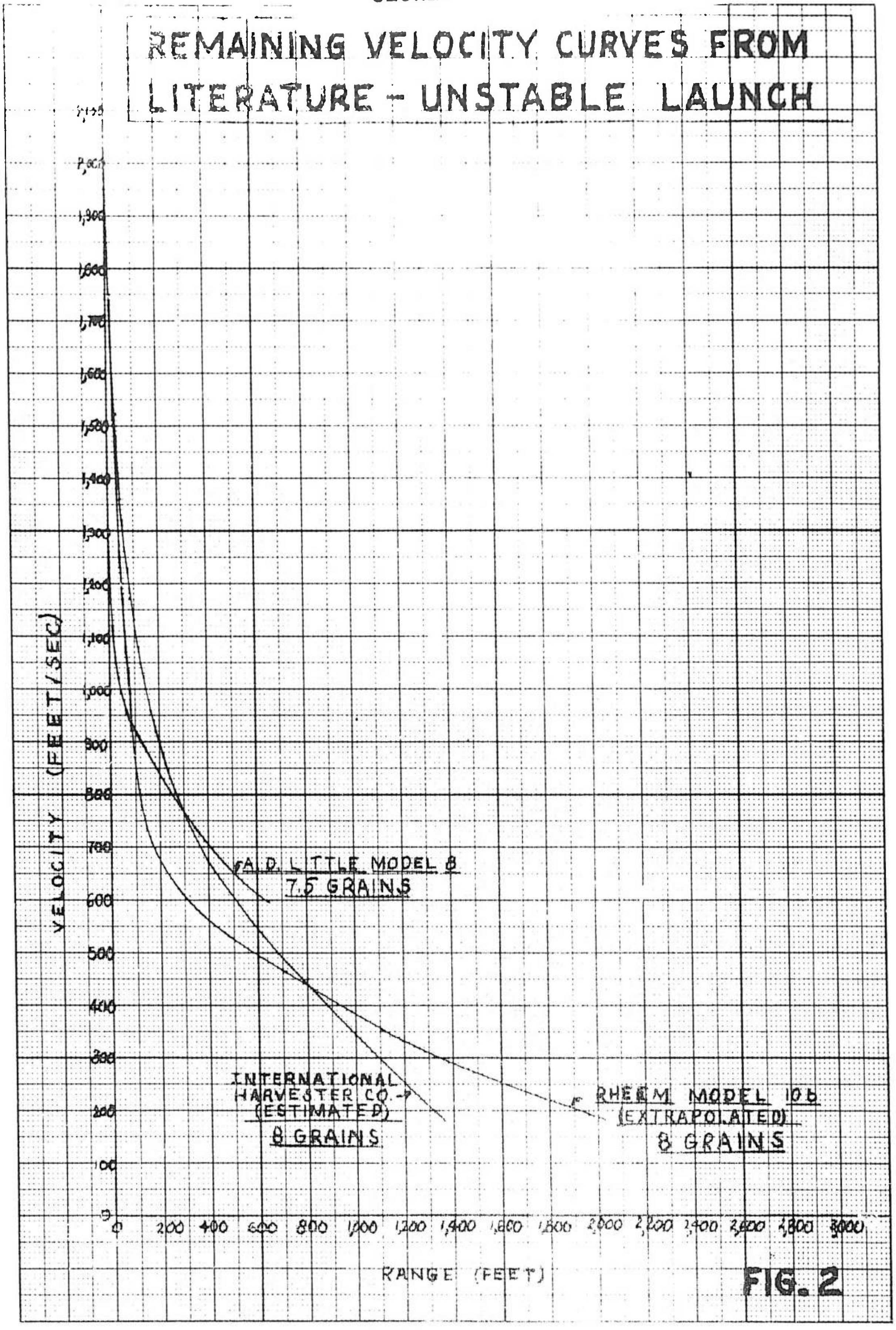

REMAINING VELOCITY CURVES FROM LITERATURE - UNSTABLE LAUNCH
VELOCITY (FEET/SEC)
RANGE (FEET)
A.D. LITTLE MODEL 8
7.5 GRAINS
INTERNATIONAL HARVESTER CO.
(ESTIMATED)
8 GRAINS
RHEEM MODEL 106
(EXTRAPOLATED)
8 GRAINS
0 200 400 600 800 1,000 1,200 1,400 1,600 1,800 2,000 2,200 2,400 2,600 2,800 3,000
0 100 200 300 400 500 600 700 800 900 1,000 1,100 1,200 1,300 1,400 1,500 1,600 1,700 1,800 1,900

FIG. 2

REMAINING VELOCITY CURVES FROM LITERATURE – UNSTABLE LAUNCH

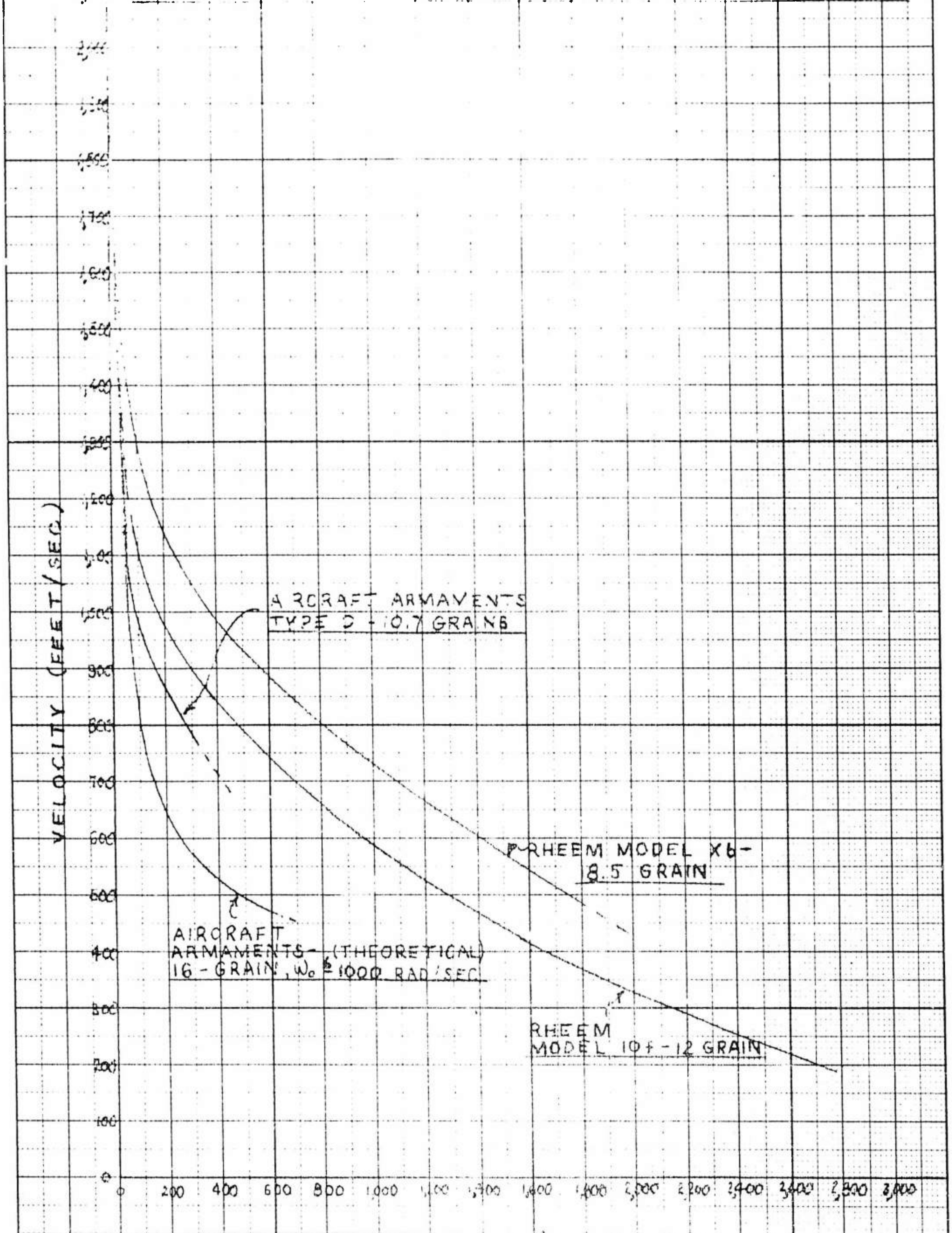


FIG. 3

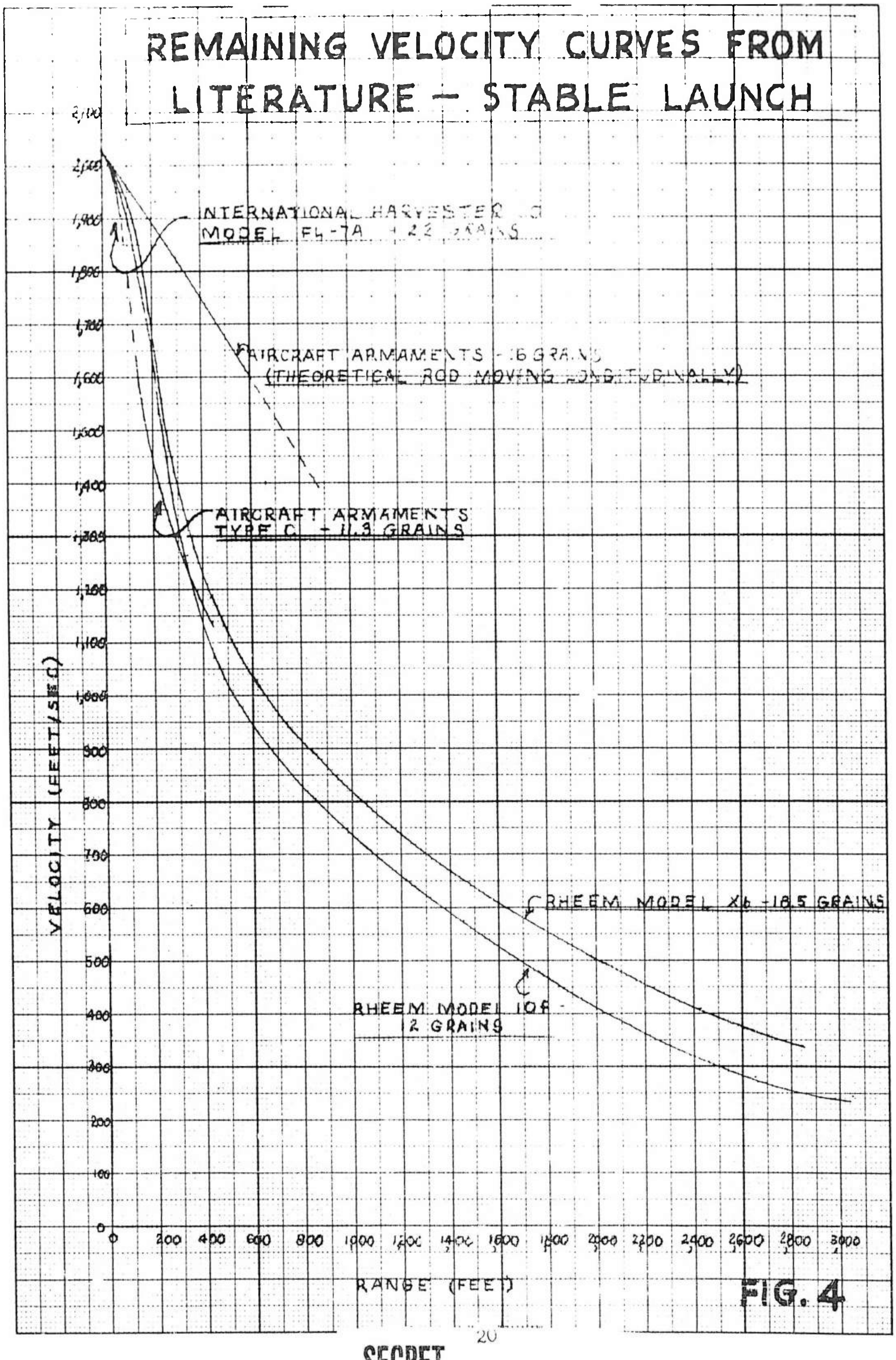

REMAINING VELOCITY CURVES FROM LITERATURE — STABLE LAUNCH
INTERNATIONAL HARVESTER
MODEL F4-7A
AIRCRAFT ARMAMENTS
(THEORETICAL ROD MOVING
AIRCRAFT ARMAMENTS
TYPE C + 11.3 GRAINS
RHEEM MODEL X6 +18.5 GRAINS
RHEEM MODEL 10F
12 GRAINS
VELOCITY (FEET/SEC)
RANGE (FEET)
0
100
200
300
400
500
600
700
800
900
1,000
1,100
1,200
1,300
1,400
1,500
1,600
1,700
1,800
1,900
2,000
2,100
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
2,600
2,800
3,000

FIG. 4

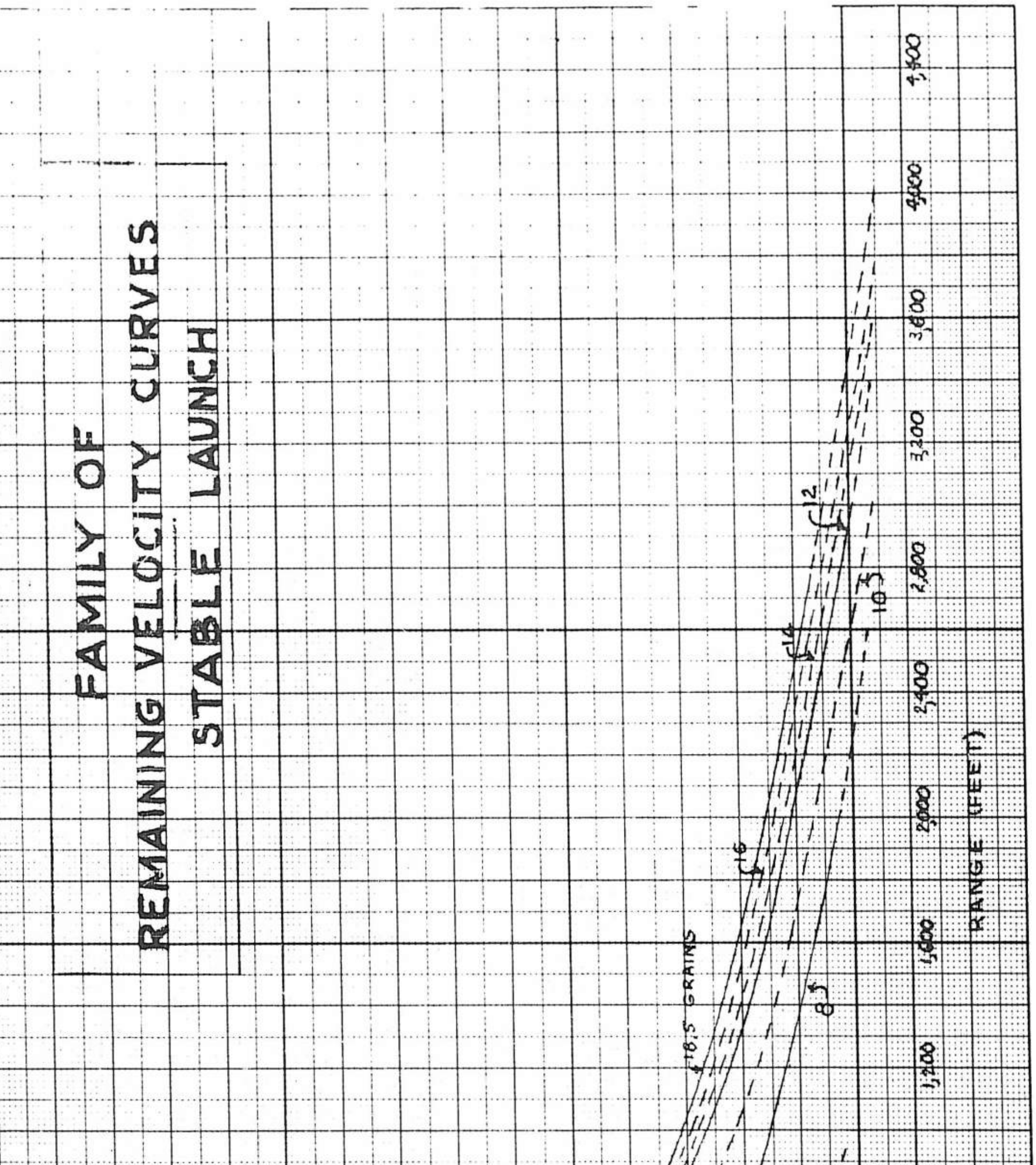

FAMILY OF
REMAINING VELOCITY CURVES
STABLE LAUNCH
18.5 GRAINS
16
14
12
10.5
8.5
6.7
RANGE (FEET)
VELOCITY (FEET/SEC)
0
400
800
1,200
1,600
2,000
2,400
2,800
3,200
3,600
4,000
4,400
200
600
1,000
1,400
1,800
2,200

FIG.5

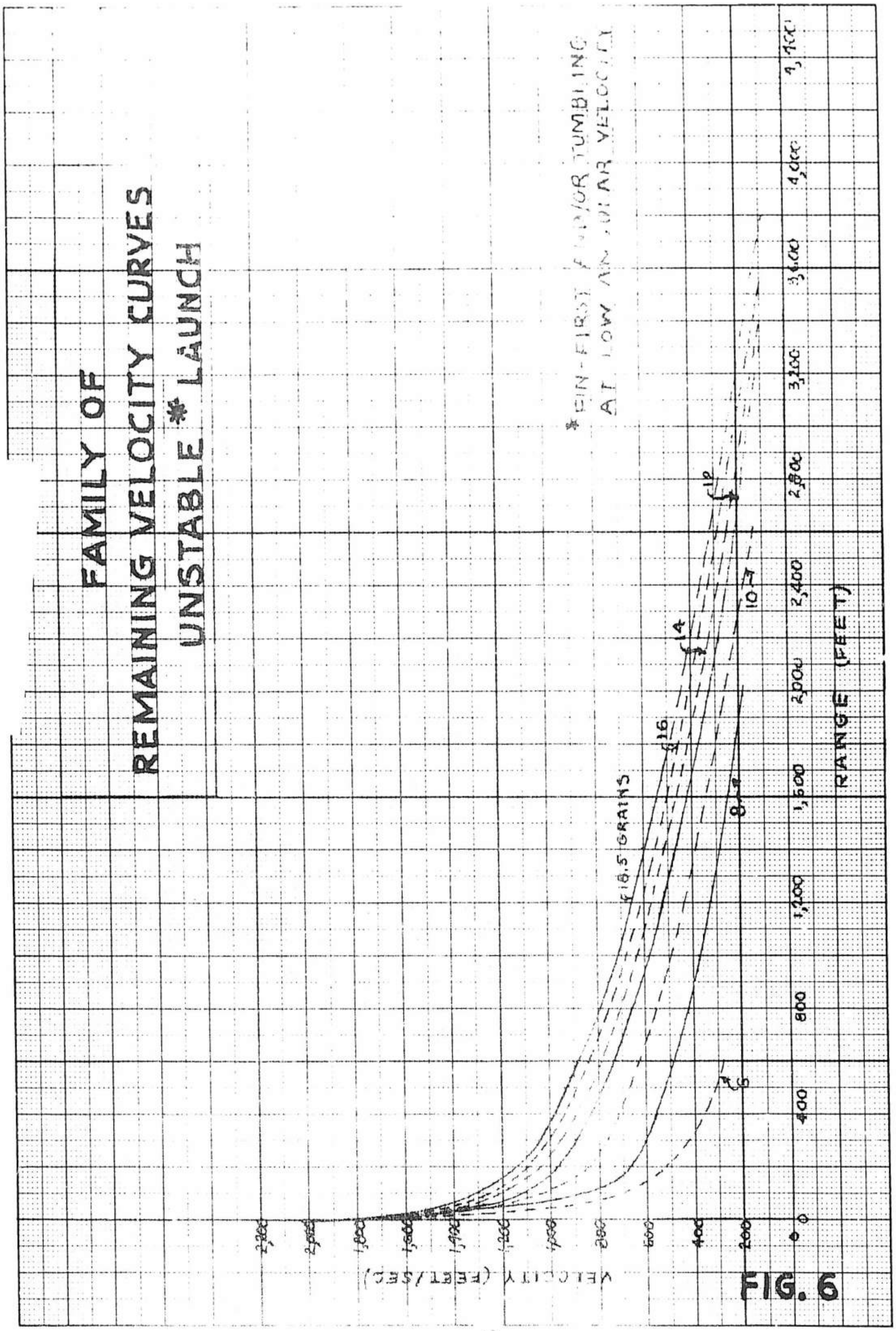
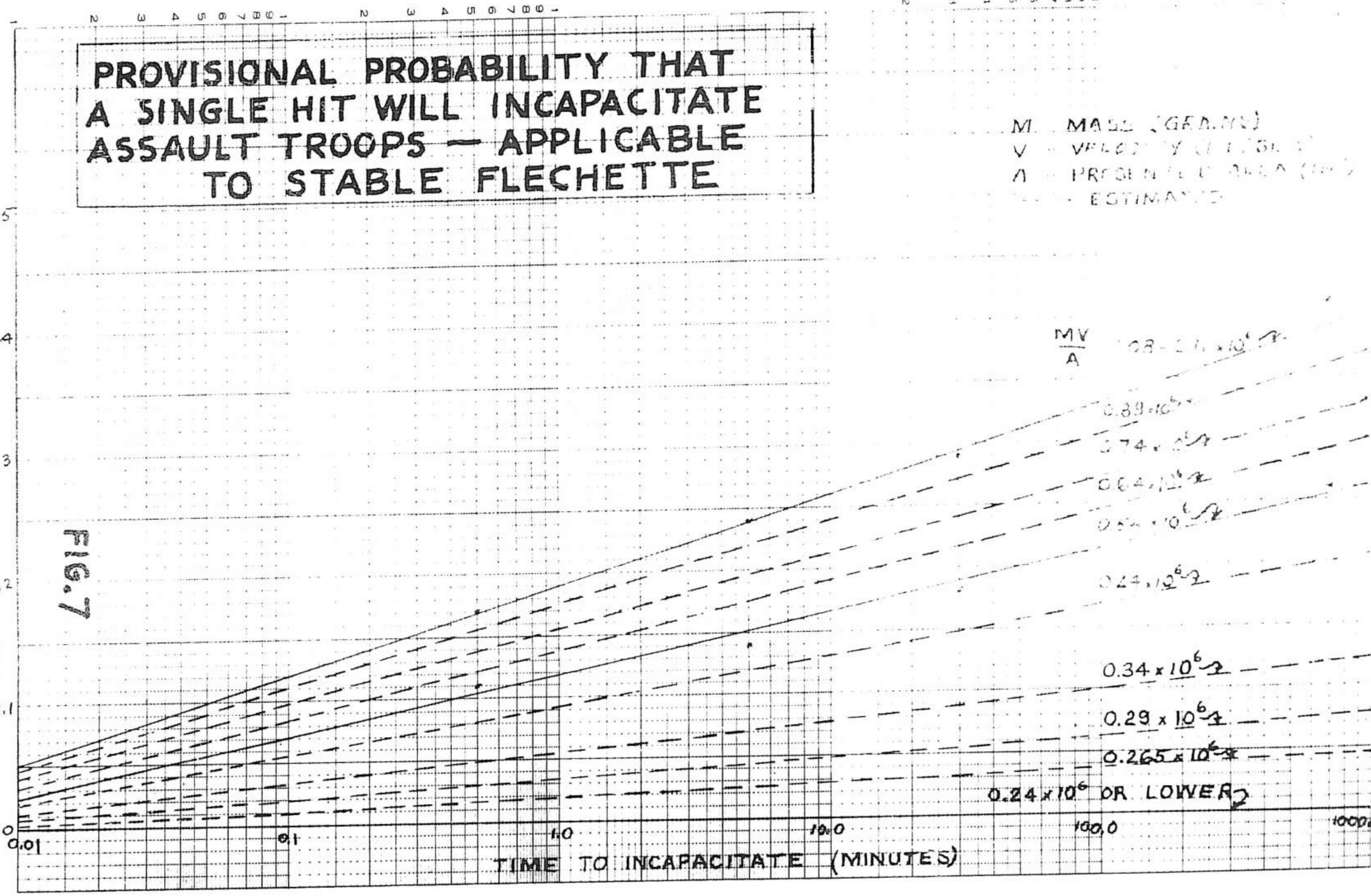

FAMILY OF
REMAINING VELOCITY CURVES
UNSTABLE * LAUNCH
* FIN-FIRST AND/OR TUMBLING
AT LOW ANGULAR VELOCITY
18.5 GRAINS
16
14
12
10
8
6
RANGE (FEET)
0
400
800
1,200
1,600
2,000
2,400
2,800
3,200
3,600
4,000
4,400
VELOCITY (FEET/SEC)
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200

FIG. 6

SECRET



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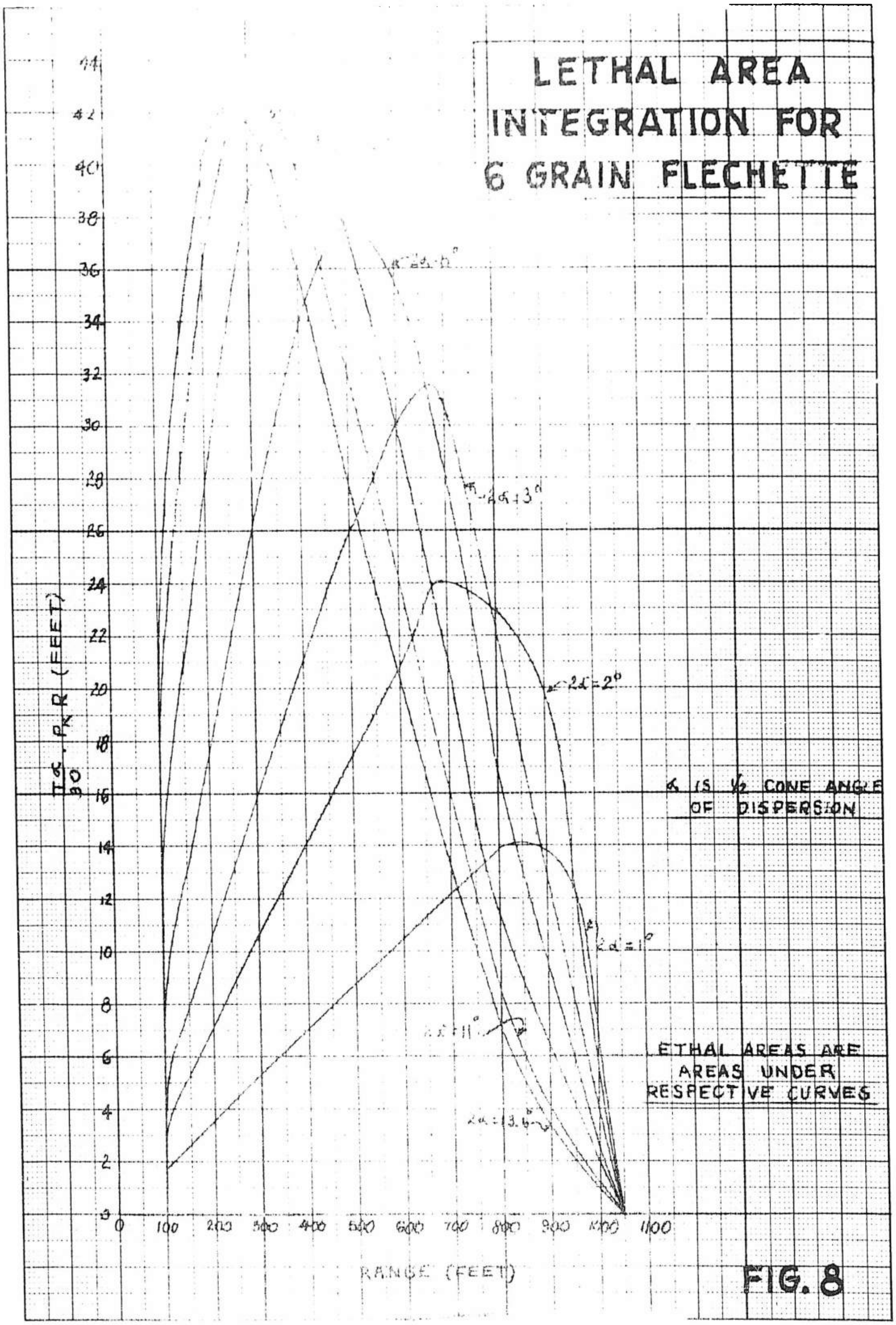
LETHAL AREA
INTEGRATION FOR
6 GRAIN FLECHETTE
α IS ½ CONE ANGLE
OF DISPERSION
LETHAL AREAS ARE
AREAS UNDER
RESPECTIVE CURVES
2α = 3°
2α = 2°
2α = 1°
RANGE (FEET)

FIG. 8

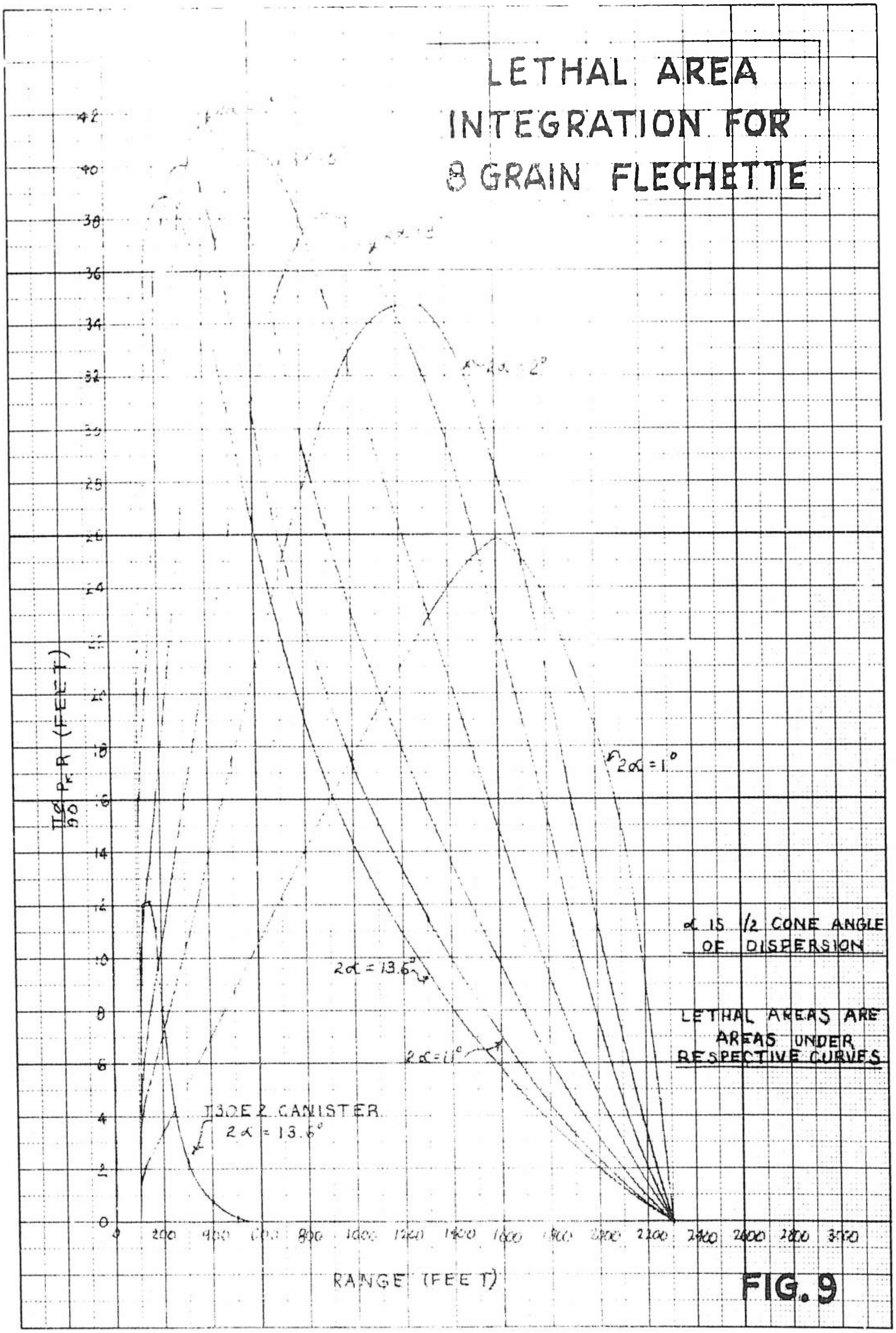
LETHAL AREA INTEGRATION FOR 8 GRAIN FLECHETTE
$\frac{\pi\alpha}{90} P_K R$ (FEET)
RANGE (FEET)
$2\alpha = 2°$
$2\alpha = 1°$
$2\alpha = 13.6°$
$2\alpha = 11°$
T30E2 CANISTER $2\alpha = 13.6°$
α IS 1/2 CONE ANGLE OF DISPERSION
LETHAL AREAS ARE AREAS UNDER RESPECTIVE CURVES
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000

FIG. 9

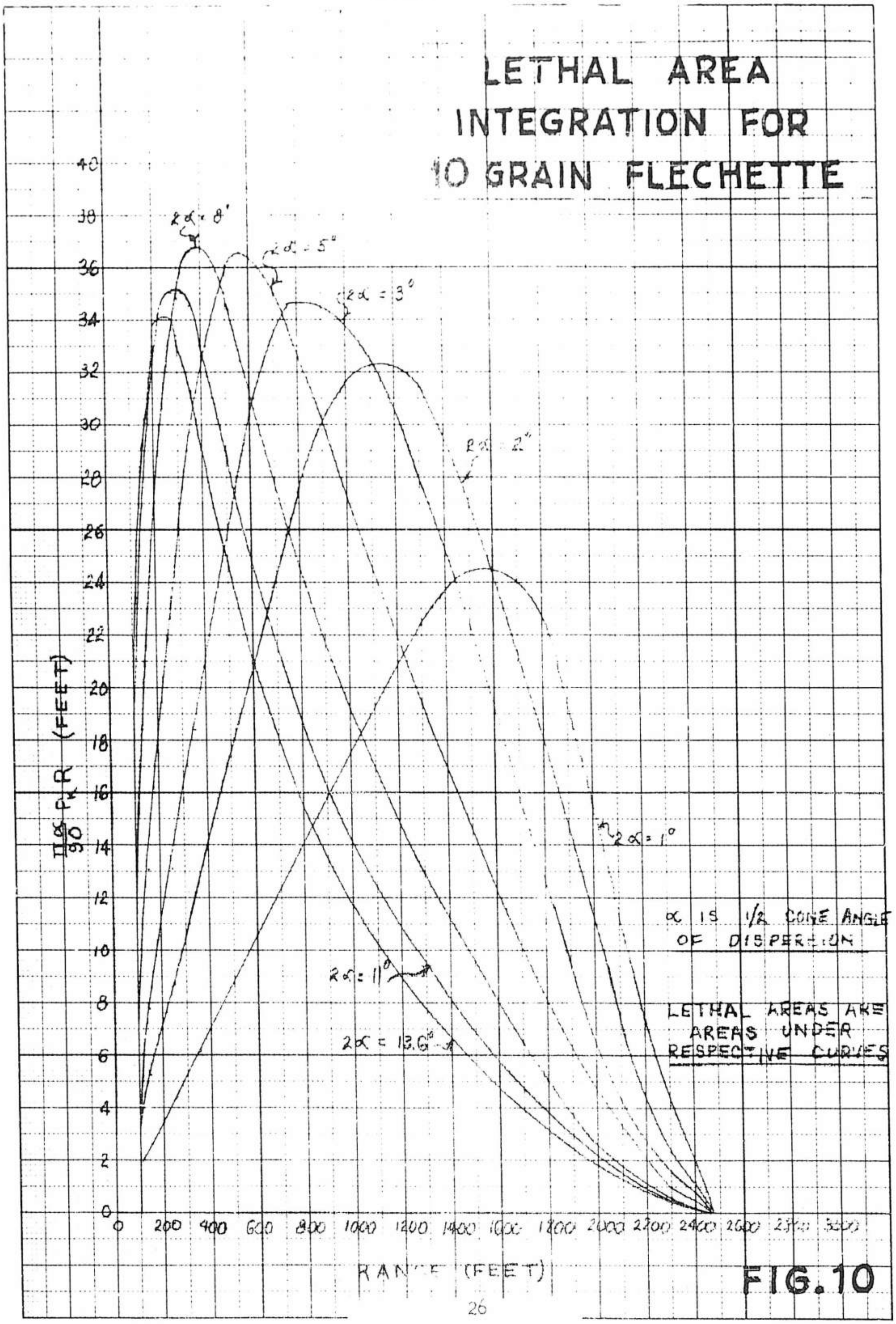
LETHAL AREA INTEGRATION FOR 10 GRAIN FLECHETTE
$2\alpha = 8°$
$2\alpha = 5°$
$2\alpha = 3°$
$2\alpha = 2°$
$2\alpha = 1°$
$2\alpha = 11°$
$2\alpha = 13.6°$
α IS 1/2 CONE ANGLE OF DISPERSION
LETHAL AREAS ARE AREAS UNDER RESPECTIVE CURVES
$\frac{\pi\alpha}{90} P_K R$ (FEET)
RANGE (FEET)

FIG.10

SECRET

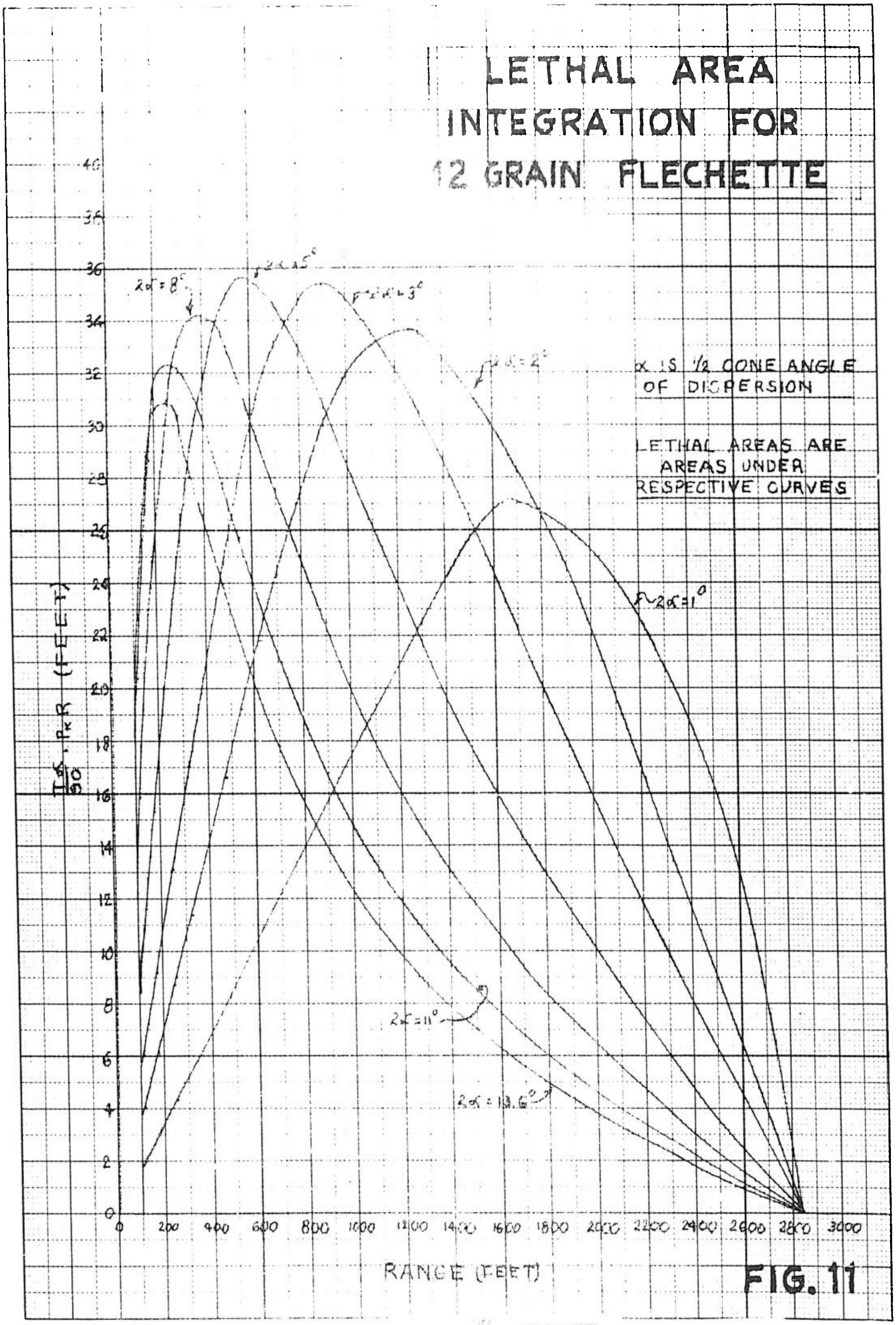

FIG. 11

SECRET

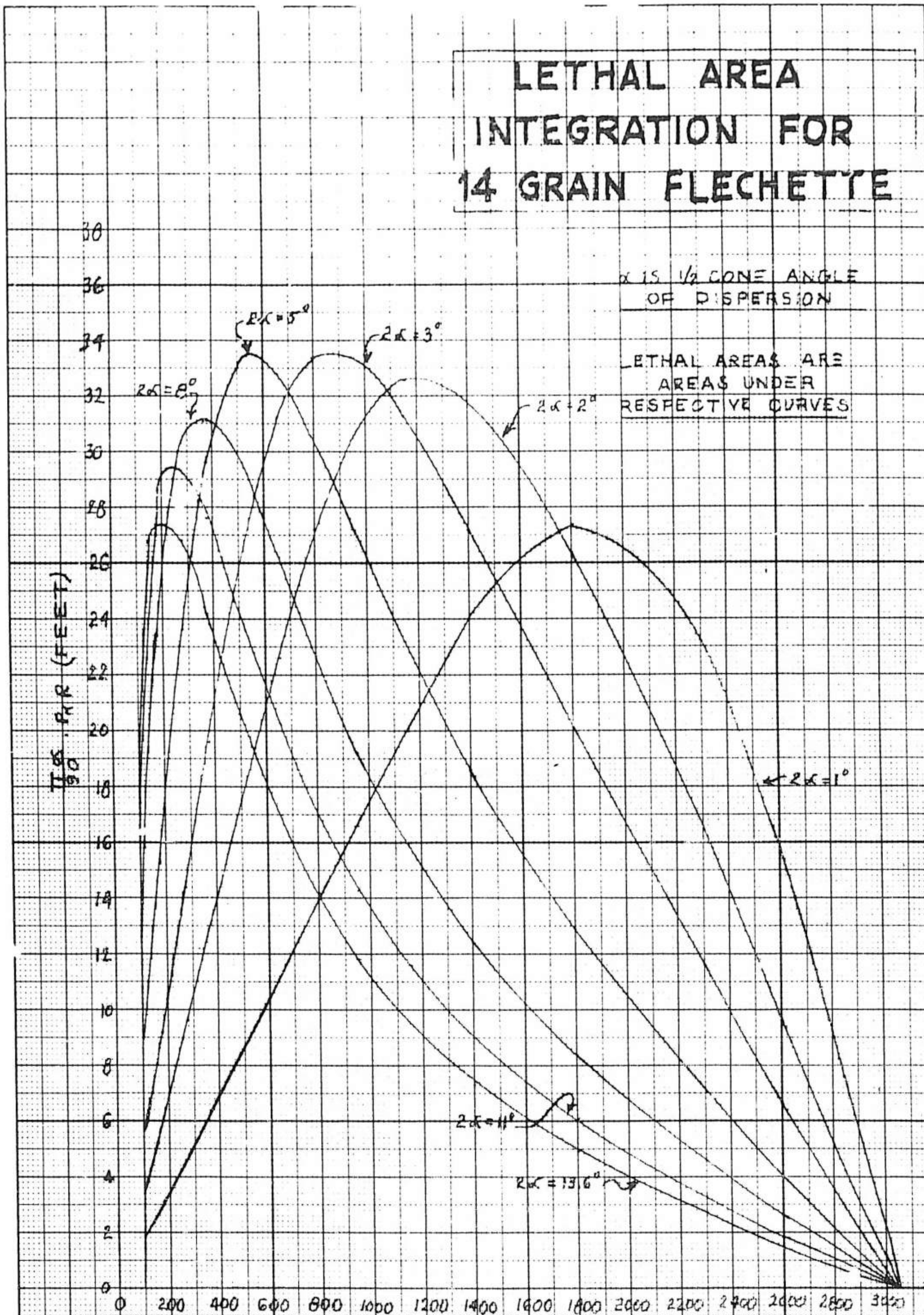
LETHAL AREA INTEGRATION FOR 14 GRAIN FLECHETTE
α IS 1/2 CONE ANGLE OF DISPERSION
LETHAL AREAS ARE AREAS UNDER RESPECTIVE CURVES
2α = 5°
2α = 3°
2α = 8°
2α = 2°
2α = 1°
2α = 11°
2α = 13.6°
RANGE (FEET)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38

FIG. 12

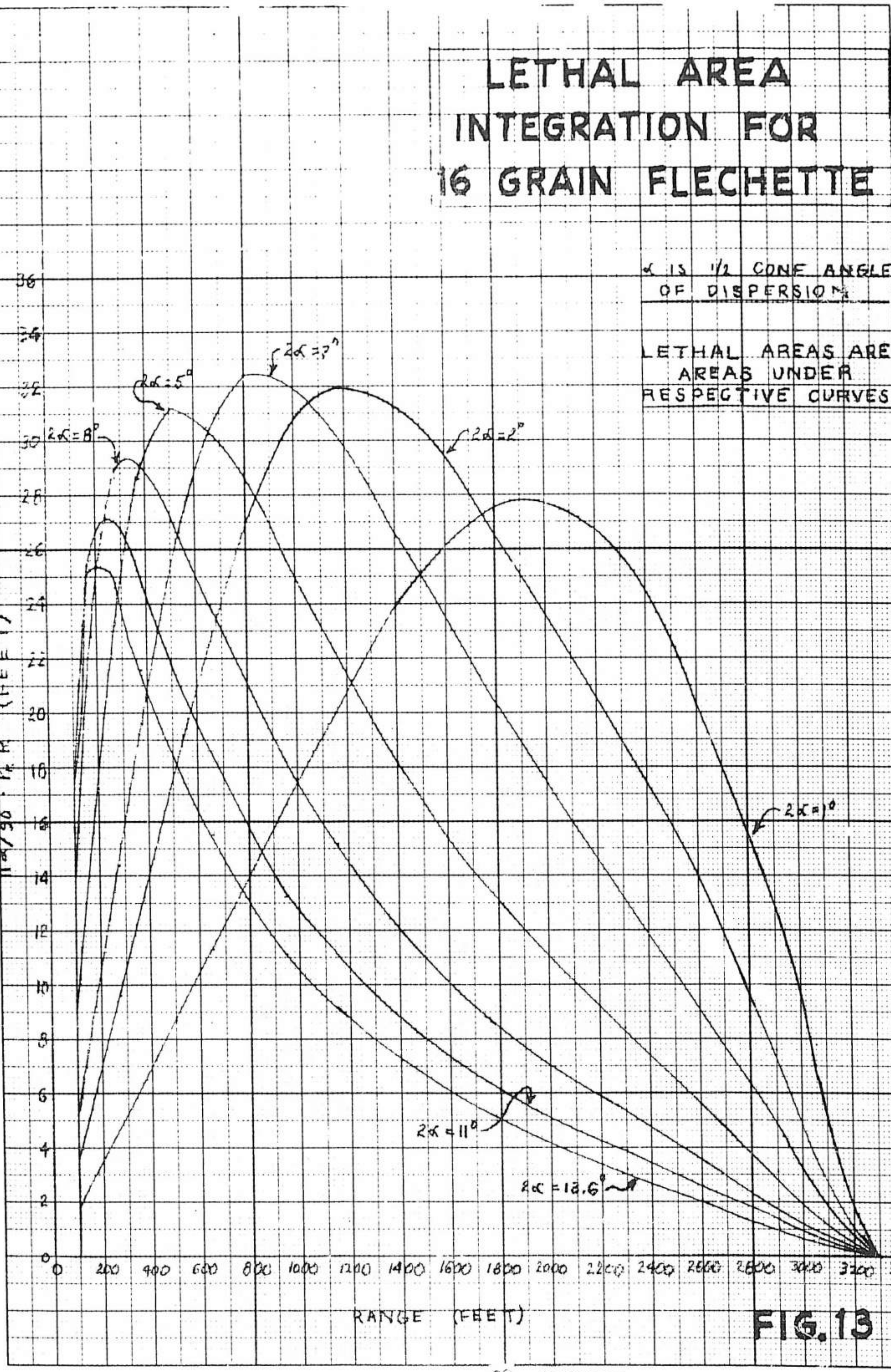
LETHAL AREA
INTEGRATION FOR
16 GRAIN FLECHETTE
α IS 1/2 CONE ANGLE OF DISPERSION
LETHAL AREAS ARE AREAS UNDER RESPECTIVE CURVES
2α = 7°
2α = 5°
2α = 8°
2α = 2°
2α = 1°
2α = 11°
2α = 18.6°
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
RANGE (FEET)

FIG. 13

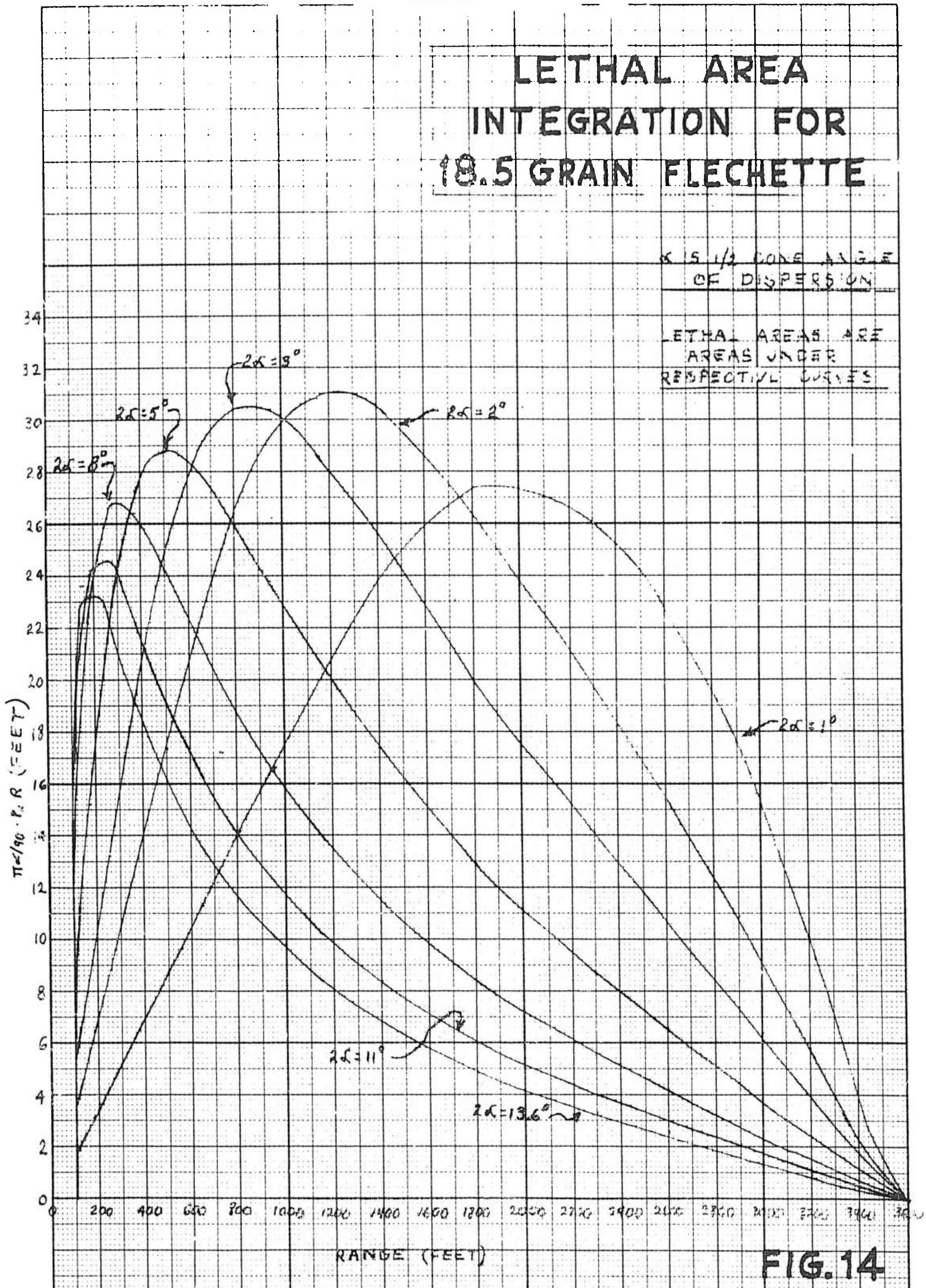
LETHAL AREA
INTEGRATION FOR
18.5 GRAIN FLECHETTE
OF DISPERSION
LETHAL AREAS ARE
AREAS UNDER
2α = 3°
2α = 5°
2α = 8°
2α = 2°
2α = 1°
2α = 11°
2α = 13.6°
RANGE (FEET)

FIG. 14

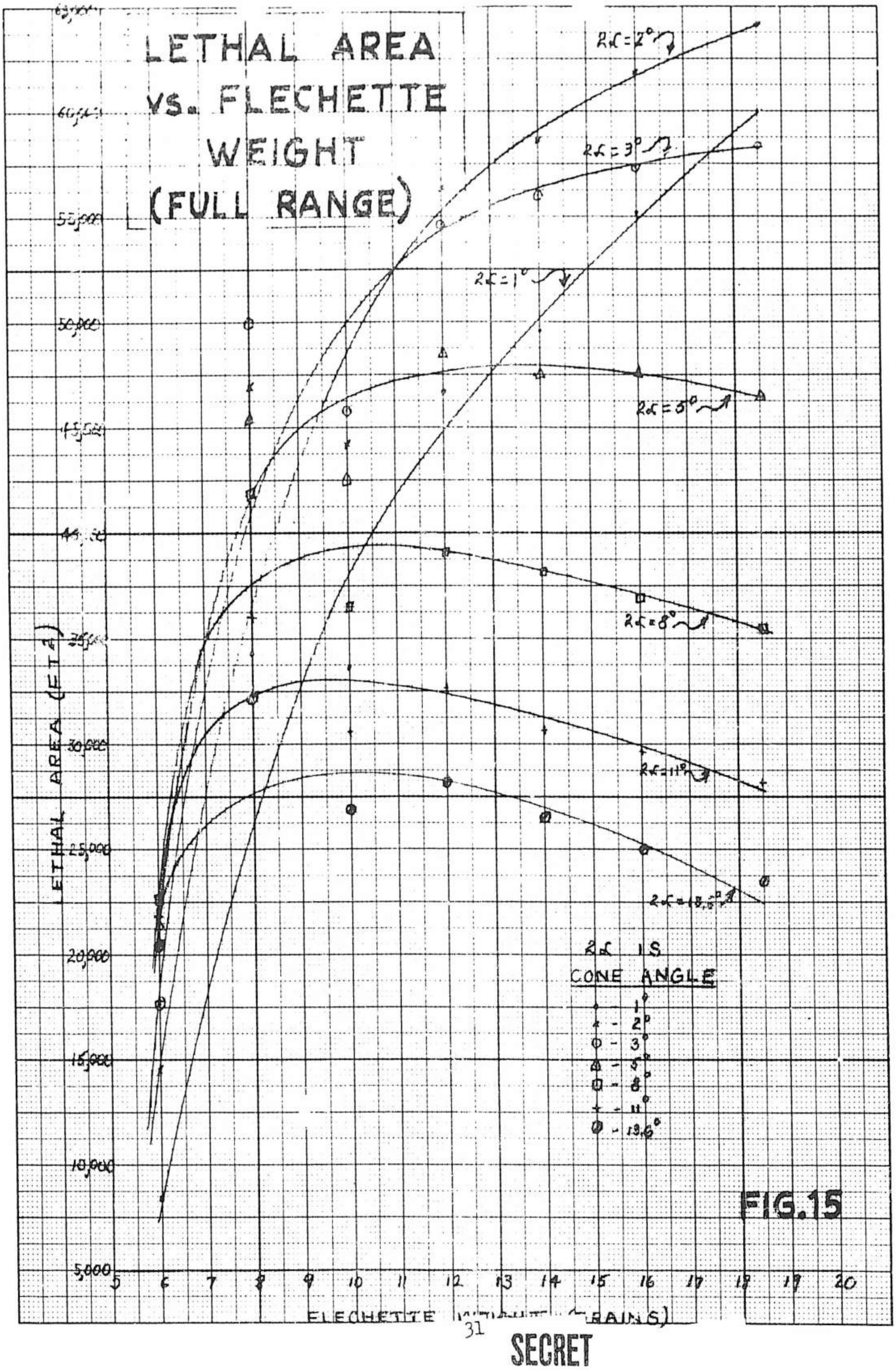
LETHAL AREA vs. FLECHETTE WEIGHT (FULL RANGE)
LETHAL AREA (FT²)
FLECHETTE WEIGHT (GRAINS)
2α = 2°
2α = 3°
2α = 1°
2α = 5°
2α = 8°
2α = 11°
2α = 13.6°
2α IS CONE ANGLE
1°
2°
3°
5°
8°
11°
13.6°
5,000
10,000
15,000
20,000
25,000
30,000
35,000
45,000
50,000
55,000
60,000
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

FIG.15

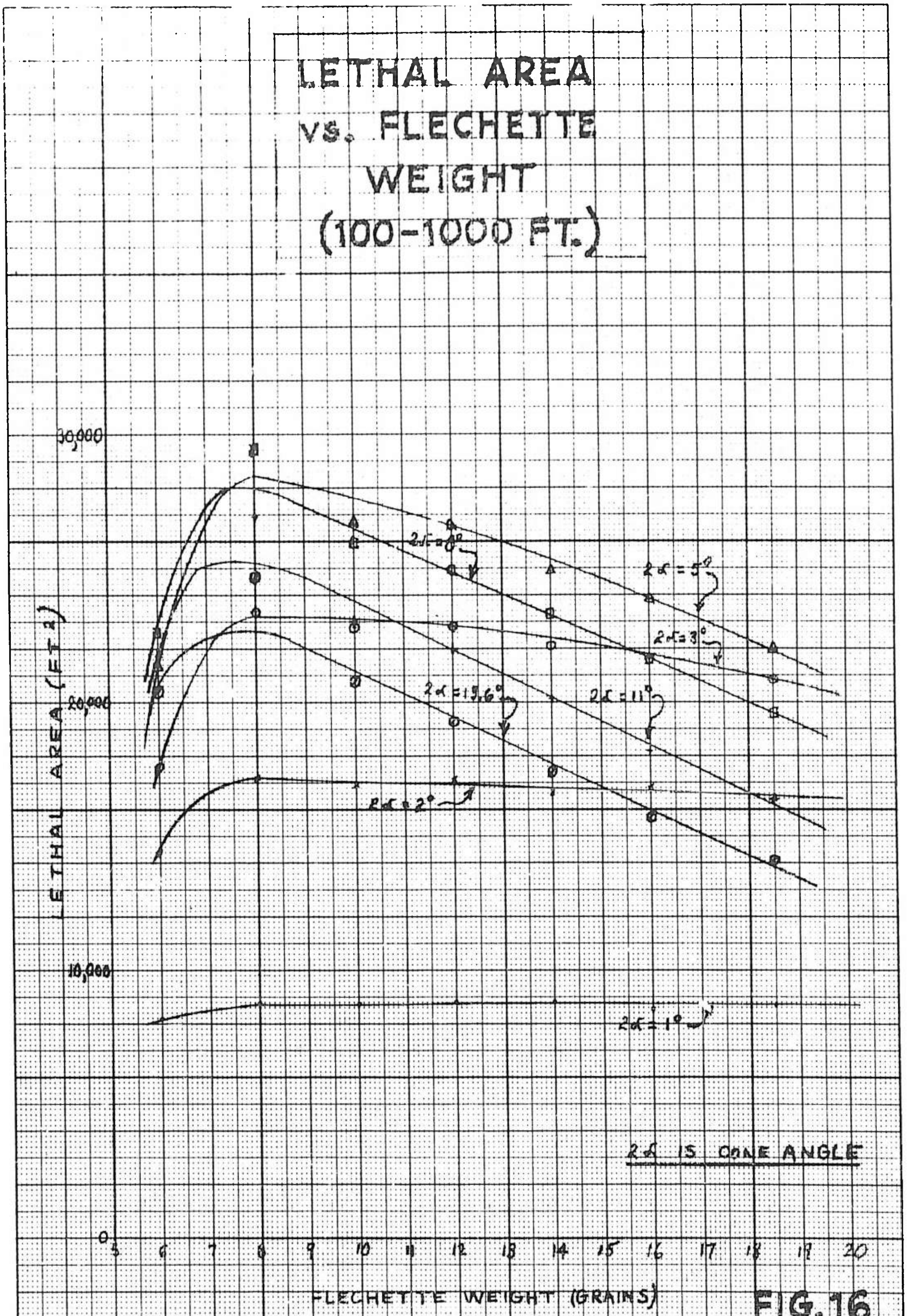
LETHAL AREA
vs. FLECHETTE
WEIGHT
(100-1000 FT.)
LETHAL AREA (FT 2)
30,000
20,000
10,000
0
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
FLECHETTE WEIGHT (GRAINS)
2α = 8°
2α = 5°
2α = 3°
2α = 15.6°
2α = 11°
2α = 2°
2α = 1°
2α IS CONE ANGLE

FIG. 16

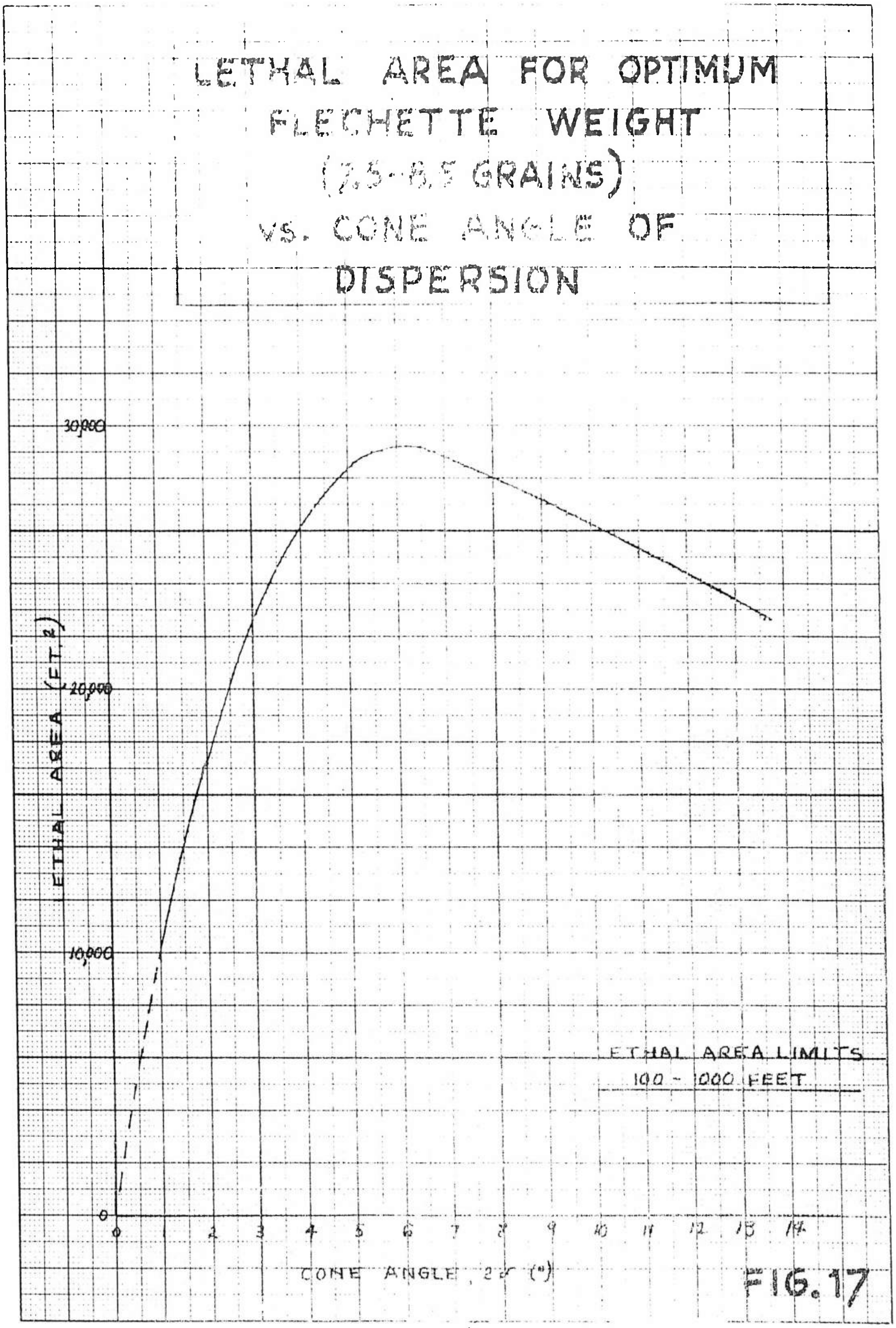
LETHAL AREA FOR OPTIMUM
FLECHETTE WEIGHT
(2.5-8.5 GRAINS)
vs. CONE ANGLE OF
DISPERSION
30,000
20,000
10,000
0
LETHAL AREA (FT.2)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
LETHAL AREA LIMITS
100 - 1000 FEET
CONE ANGLE, 2α (°)

FIG. 17

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